

**NATIONAL TRANSPORTATION SAFETY BOARD  
Office of Research and Engineering  
Vehicle Recorder Division  
Washington, DC 20594**



**GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION  
Cockpit Image Recorder – Group Chairman's Factual Report  
DCA15MA019**

**By  
Sean Payne**

**WARNING**

The reader of this report is cautioned that the transcription of an onboard image and audio recording is not a precise science but is the best product possible from a Safety Board group investigative effort. The transcript or parts thereof, if taken out of context, could be misleading. The transcript should be viewed as an accident investigation tool to be used in conjunction with other evidence gathered during the investigation. Conclusions or interpretations should not be made using the transcript as the sole source of information.

# NATIONAL TRANSPORTATION SAFETY BOARD

Vehicle Recorder Division  
Washington, DC 20594

December 16, 2014

## Cockpit Image Recorder

### Group Chairman's Factual Report By Sean Payne

#### 1. EVENT

Location: Koehn Dry Lake, CA  
Date: October 31, 2014  
Aircraft: Scaled Composites SpaceShipTwo  
Registration: N339SS  
Operator: Scaled Composites  
NTSB Number: DCA15MA019

#### 2. GROUP

An onboard image recorder transcription group was convened on November 18, 2014. The members of the group were:

Chairman:	Sean Payne Mechanical Engineer National Transportation Safety Board
Member:	Henry Lampazzi Aerospace Engineer Federal Aviation Administration – Commercial Space Transportation
Member:	Clint Nichols Test Pilot Scaled Composites
Member:	David Mackay Chief Pilot Virgin Galactic

### 3. SUMMARY

On October 31, 2014, about 1007 Pacific daylight time, a Scaled Composites SpaceShipTwo (SS2) reusable suborbital rocket, N339SS, experienced an in-flight anomaly during a rocket-powered flight test, resulting in loss of control of the vehicle. SS2 broke up into multiple pieces and impacted terrain over a 5-mile area near Koehn Dry Lake, California. One test pilot (the copilot) was fatally injured, and the other test pilot was seriously injured. SS2 had launched from the WhiteKnightTwo (WK2) carrier aircraft, N348MS, about 12 seconds before the loss of control. SS2 was destroyed, and WK2 made an uneventful landing. Scaled Composites was operating SS2 under an experimental permit issued by the Federal Aviation Administration's (FAA) Office of Commercial Space Transportation under the provisions of 14 *Code of Federal Regulations* (CFR) Part 437.

### 4. DETAILS OF INVESTIGATION

On November 3, 2014, the NTSB Vehicle Recorder Division's Audio/Video Laboratory representative received the following files:

File:	<b>VideoChannel1.avi</b>
File:	<b>VideoChannel1_Part2.avi</b>
File:	<b>VideoChannel1_Part3.avi</b>
Equipment:	<b>Imperx Bobcat SD1-B1921C</b>

#### 4.1. ***Strap On Data Acquisition System (SODAS) Telemetry System***

##### 4.1.1. **Recorder Description**

The recording used for this video transcript report was obtained from the SODAS (Strap-On Data Acquisition System) telemetry ground station located in the mission control room at Scaled's location on the Mojave Airport grounds. On SpaceShipTwo, the video was processed from an Imperx Bobcat camera. The digital camera signal was processed into an analog NTSC<sup>1</sup> signal and then sent to an ACRA-103 module onboard the spaceship for the addition of a digital timestamp. The video data was then encoded into PCM<sup>2</sup> frames and sent via the telemetry system to the ground station.

The Imperx Bobcat camera is a high quality, small size, 2/3" color CCD<sup>3</sup> camera that allows the user to control a number of programmable features and communicates via GigE<sup>4</sup>. It has an operating temperature range of -40° Celsius (C) to +85°C and shock and vibration performance of greater than 1000G and 100G, respectively. The camera is suited for onboard video applications in extreme environments. The camera has a maximum resolution of 1952 x 1112 pixels at a frame rate of 39 frames per second (fps) in color. The camera was outfitted with a Kowa 5mm f/1.8 lens.

---

<sup>1</sup> NTSC – National Television Signal Committee. An analog television standard.

<sup>2</sup> PCM – Pulse-Code Modulation. A method to digitally represent analog signals.

<sup>3</sup> CCD – Charged-coupled device. An image sensor that allows conversion of areas of electrical charge to a digital value.

<sup>4</sup> GigE – An interface standard for high-performance industrial and machinevision cameras.

#### **4.1.2. Recorder Damage**

The files were received upon file transfer from the ground via encrypted USB thumb drive. The files did not exhibit any file corruptions or difficulties resulting from premature power loss.

#### **4.1.3. Audio/Video Channels**

Metadata<sup>5</sup> written to the video track shows the files were recorded to the telemetry ground station at a frame rate of 30 fps and a resolution of 704 x 288. The video resolution is consistent with the video being transmitted by the telemetry system by individual field<sup>6</sup> segments to reduce transmission bandwidth<sup>7</sup>. This resulted in the ground station recording a stretched aspect ratio<sup>8</sup> of the telemetered video source. Since each field contains roughly half the vertical resolution of the total frame size by definition, the aspect ratio was changed in post processing to account for the stretch created by the video field transmission. This resulted in roughly a 4:3 aspect ratio and a resolution of 704x576<sup>9</sup>. The frame rate remained unchanged for the recording.

The video camera that recorded the telemetered video was positioned in the SpaceShipTwo crew module directly behind and between the pilot and copilot crew stations. It captured a view over the shoulder of both crew members and most of the instrument panel and flight controls. A small outboard portion of either side of the instrument panel was not directly in view of the camera. At times, movement by the pilot and copilot in their seats allowed previously unseen portions of the instrument panel to be briefly visible. Figure 1 is a digital illustration of the camera field of view created using a screenshot from the onboard image recorder in the original aspect ratio as recorded by the telemetry groundstation.

**Figure 1. A rendering of field of view of the cockpit image recorded onboard SS2.**



The recording also consisted of two channels of audio information, both a left and right audio track recorded at 16,000Hz. The right channel of the audio recording received the pilot's mic in an un-switched<sup>10</sup> and open state, communications over the intercom system between SpaceShipTwo and WhiteKnightTwo when captive as well as

<sup>5</sup> Metadata – A subset of data containing time, date, file size, resolution and audio information.

<sup>6</sup> Fields – One half of the vertical resolution information in an interlaced display.

<sup>7</sup> Bandwidth – The rate of data transfer, bit rate or throughput, measured in bits per second (bit/s).

<sup>8</sup> Aspect Ratio – A factor describing the proportional relationship between an image's width and height.

<sup>9</sup> 704x476 – 4CIF – Common Intermediate Format – A resolution consistent with DVD video.

<sup>10</sup> Un-Switched – A condition where the recorder continually receives audio input without applying a squelch threshold.

VHF communications between SpaceShipTwo and other entities. The right audio track picked up continuous breathing of the pilot throughout the flight which masked VHF transmissions in portions of the transcript. Audio of the pilot's breathing would not have been heard by any of the crew through their headsets unless the audio level met a squelch threshold set on the intercom panel, and thus portions of the transcript containing unintelligible VHF audio transmissions would have likely been heard clearly by the crew. The right track also received the pilot and co-pilot's sidetone<sup>11</sup> during VHF transmissions from SpaceShipTwo.

The left audio track contained the co-pilot's mic in a VOX<sup>12</sup> state, as processed through SpaceShipTwo's audio panel. In this manner, the recorded audio from the left channel contained audio based on SpaceShipTwo's intercom output. It contained the pilot and co-pilot's voice as well as transmissions between SpaceShipTwo and WhiteKnightTwo over the intercom system. Unlike the pilot's output, the co-pilot's channel did not transmit the sound of the co-pilot's breathing as the output was mixed through the audio panel and limited by a squelch setting.

#### **4.1.4. Timing and Correlation**

Timing was established by correlating the IRIG<sup>13</sup> timestamp in the video track's metadata to the recorded images and audio. This timestamp is unique and separate from the displayed IRIG graphic overlay that is present on the original source video. The displayed IRIG graphic overlay present on the original source video is a result of a transmission from the system's ACRA VID-103 module and is known to be incorrect by up to 0.9 seconds. For the purpose of this report, the displayed IRIG graphic overlay was not used and only the video and audio track's metadata IRIG timestamp was used as a source of absolute timing information. The timing information derived from the video's metadata was created by the telemetry receiver which was fed an IRIG time source from a GPS receiver located in the ground station. Since the video timestamp was synced to an IRIG time system, it was assumed to match the flight data source telemetered, which was also fed an IRIG timing source.

Upon review, the alignment of the audio track to the video track appeared to be slightly out of position. Audio video correlation in multiple regions of the recording were marginally out of alignment, such that the audio track was delayed in comparison to the recorded images. The audio and video track alignment was analyzed in a non-linear<sup>14</sup> video editing software and it was determined that the audio was delayed by 12.1 frames (+0.403 seconds). This was corrected by importing the original telemetry recording and associated audio tracks into the non-linear video editing software. In the software, the associated audio tracks were split from the video recording and examined. The editing software showed an audio trace of the recorded audio track. A spike in the trace associated with the sound of the release of SpaceShipTwo from WhiteKnightTwo's central pylon was used to realign the audio tracks to the video. Delaying the audio 12.1

---

<sup>11</sup> Sidetone – a type of audio feedback where sound picked up by the crew's microphone's, usually during a VHF transmission, is fed back into the earpiece of the crew's headsets.

<sup>12</sup> VOX – Voice Operated Exchange - A voice operated switch that is activated when a sound is detected above a specified squelch threshold in place of a user pushing a button to transmit.

<sup>13</sup> IRIG - Inter-Range Instrumentation Group – A standard for range timing information.

<sup>14</sup> Non-linear video editing software – A digital editing system which performs non-destructive changes of the source material.

frames moved the noise associated with release into correlation with the recorded images.

The audio and video track was aligned manually using video editing software and is subject to some degree of uncertainty. The group's best investigative assessment of the time correlation is used in this transcript. For events in close proximity, the sequence of events should be interpreted with caution.

#### **4.1.5. Summary of Recording Contents Prior to Transcript Start**

Each of the three recorded video files was determined to contain an audio recording of good quality.<sup>15</sup> Metadata shows VideoChannel1.avi began at 08:02:47.608 UTC on the accident day. VideoChannel1\_part2.avi began at 12:07:29.889 UTC on the accident day and VideoChannel1\_part3.avi began at 15:34:46.224 UTC. In consultation with the investigative team, only a portion of each recording that contained the crew was documented in this report. In this manner, the first crew member entered the cockpit on recording VideoChannel1\_part2.avi at approximately 15:10:40 UTC. VideoChannel1\_part2.avi terminates at approximately 15:34:46 UTC when VideoChannel1\_part3.avi begins shortly thereafter. Furthermore, the first portion of the audio/video recordings were summarized from the time the first crew member entered the cockpit (15:10:40 UTC) until approximately 16:28:20 UTC when the SpaceShipTwo crew experienced a multi-function display (MFD) system reboot. A complete audio and video transcript was documented covering the time from the MFD system reboot (16:28:20 UTC) until the termination of the recording at 17:07:32.800 UTC. The summary is included below and the complete transcript is included as an attachment at the end of section 4 of this report.

The summarized portion of the recordings begins at approximately 15:10:40 UTC, when the co-pilot entered the cockpit briefly and placed some items near a seat and then moved from the camera's view. By 15:13:40, the co-pilot re-entered the camera's view and began securing himself in the right seat. Shortly after the pilot entered the cockpit (15:15:45 UTC) and began securing himself in the left seat. The crew members proceeded to secure their ear plug style communications devices in their ears and began securing their helmets. Shortly after, the crew members connected their headsets to the audio panel, the crew performed a communications check on hot mic at approximately 15:21:30 UTC and then they performed a second communications check on mission frequency. At roughly 15:22:15 UTC, the crew conducted and completed the "After Entering Cockpit" checklist, followed shortly by the crew executing the cockpit power up sequence. At 15:25:00 UTC, Scaled Mission Control made a request to power down the Strap On Data Acquisition System (DAS) instrumentation system to perform a CF (compact flash) card swap. From this point until the end of file VideoChannel1\_part2.avi, the copilot continued to flip through MFD pages and talked through nominal checklist items with the pilot. Some of the checks included in this timeframe contained Reaction Control System (RCS) and trim panel checks, L-3 check, a brief discussion of Pressurization System Controller (PSC) status, pneumatics checks, Environmental Control System (ECS) checks, ECS temps checks and rocket page checks. VideoChannel1\_part2.avi then terminates.

---

<sup>15</sup> See Attachment 1 – Audio Quality Rating Scale

The ground station recording segmented and VideoChannel1\_part3.avi began. At this time, the crew was reviewing "Rocket Motor" pages on the Spaceship's MFD. The "RKT Valve" page, "RKT CTN" page and "RKT (b) (4)" page were all seen on the Spaceship's MFD and related checklists were discussed. Around 15:39:30 UTC, Intercom System (ICS) settings were checked between the WhiteKnightTwo and SpaceShipTwo crews and by 15:40:46 UTC, ICS settings were resolved.

Around 15:40:50 UTC, the SS2 crew began the feather locks check. The copilot requested "Base, you ready for unlock?" Base responded that they are ready to begin feather lock/unlock checks. The copilot moved his left hand to the feather lock handles and moved the levers to the unlocked position by 15:41:00 UTC. At the same time, a sound similar to air escaping a pressure vessel was audible. Lights associated with the proper functionality of the feather lock/unlock system were seen on the instrument panel. Base then returned with "unlock". By 15:41:11 UTC, the copilot stated "ready to lock?" and moved the feather lock handles to the locked position. Base stated "that's good lock" and the lights associated with feather locking system illuminate on the instrument panel. The copilot continued reviewing checklist items and shortly thereafter entered the "PLAN" page on the MFD.

The crew continued to review checklist items. Stab trim system, primary flight control, roll boost, dampers, speed brake, gear, brake, and window heat checks in addition to some other smaller checklist items were completed. During this time, communications from base verified most checklist items. Additionally, a ground crew member verified flight control system movements and trim checks. All checks during this time were nominal and completed without difficulty. By 15:52:00 UTC, WhiteKnightTwo executed the carrier vehicle's engine start sequence.

Around 15:55:20 UTC, a ground crew member made comments related to removing the RMC ground connector, replacing it with the maintenance connector, and began running ignitor checks. The rocket motor ignitor checks continued until around 15:57:35 UTC when the ground crew member declared that he is installing the "flight connector" and that the "rocket motor is live". The crew of WhiteKnightTwo executed after engine start checks at this time. By 16:03:10 UTC, the door of SpaceShipTwo was closed.

Around 16:06:50 UTC, PSC breakers were checked in (closed) and by 16:07:46 UTC, the pilot stated the PSC indications showed the system was unpowered. Base confirmed they are seeing the same indications in mission control. A discussion of PSC and DAU failures occurred at this time and around 16:10:37 UTC, base recommended cycling the PSC circuit breakers. At 16:11:40 UTC, the PSC circuit breakers were pushed in by the crew. By 16:13:00 UTC, base transmitted that the PSC issue seemed to be an indication issue and the crew then enabled the PSC and went to standby at around 16:13:50 UTC. Immediately following this event, the crew began to execute the pre-takeoff checklist.

At 16:15:20 UTC, the SpaceShipTwo crew reported to the WhiteKnightTwo crew that they were ready for takeoff. Shortly after, at 16:15:30 UTC, base stated that the vehicle is "green for takeoff". By 16:15:40 UTC the copilot began the line-up checklist. The copilot stated "Speedbrake..., oxygen...", at which time the pilot could be seen adjusting his oxygen mask. At that moment, a sound similar to air flow noise became more prominent. During this time, the instrument panel oxygen settings for both the pilot

and copilot appeared to be nominal for this portion of the flight activity. The copilot then stated that the line-up checklist was complete.

By 16:17:15 UTC, WhiteKnightTwo received takeoff clearance from Mojave Tower (KMHV). At around 16:18:17 UTC, takeoff roll commenced and by 16:19:05 UTC, the spacecraft and carrier vehicle began to rotate. At around 16:20:20 UTC, the pilot called for the after take-off checks. During this time, the copilot stated “alright oxygen, back to normal, mine’s to normal,” and moved on to finish the checklist. No deficiencies were indicated on the instrument panel related to oxygen system settings for both the pilot and the copilot. By 16:20:40 UTC, the after take-off check was completed.

By 16:24:32 UTC, the crew had completed the 18,000 foot checklist. All items appeared nominal. The pilot and co-pilot briefly discussed weather and noted the position of Lake Isabella. The pilot took a drink from a water bottle.

The summarized portion of the transcript ends and the detailed portion of the transcript begins at 16:28:20.078 UTC and can be found attached to this report following section 4.

#### **4.1.6. Use of Additional Recorded Material**

During the group transcription process, the group noted that certain transmissions made over VHF radio between SpaceShipTwo, WhiteKnightTwo, the Scaled mission control room and various controls were unintelligible. Alternate video and audio sources from the mission control room and from WhiteKnightTwo’s onboard cameras were used to transcribe certain unintelligible VHF transmissions for the transcript portion of this report. Comments added from the alternate recorded sources appear in this report inside dual parenthesis, and consist mostly of VHF communications.

#### **4.1.7. Surviving Crew Comments**

The surviving crew member was given the opportunity to view the recorded images and audio and comment on the transcription’s content. The surviving crew member’s only comment was related to the transcript item for Pilot-1 at 16:58:15.93 UTC. The crew member indicated that he observed himself at this time placing the oxygen switch on the oxygen regulator panel into the “Test Mask” position prior to continuing inhalation after sipping water. The crew member indicated he performed this action to preserve a continuous state of pre-breathing 100% oxygen during the appropriate portion of flight.



## **Attachment I**

### **Audio Quality Rating Scale**

The levels of recording quality are characterized by the following traits of the audio track that was recorded to the cockpit video and audio recorder:

<b>Excellent Quality</b>	Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.
<b>Good Quality</b>	Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.
<b>Fair Quality</b>	The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the image/audio system that distorts or obscures the audio information.
<b>Poor Quality</b>	Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the image/audio system that severely distorts or obscures the audio information.
<b>Unusable</b>	Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the image/audio system.

## LEGEND

<b>SS2</b>	SpaceShipTwo
<b>WK2</b>	WhiteKnightTwo
<b>RDO</b>	Push to Talk Radio Transmission over VHF
<b>HOT</b>	Flight crew audio panel voice or sound source
<b>BASE</b>	Scaled Composites Mission Control Room radio transmissions
<b>MHV-TWR</b>	Radio transmission from Mojave (KMHV) Tower
<b>Joshua-APP</b>	Joshua Approach Control Facility
<b>CHASE</b>	Radio transmission from the Scaled Composites chase aircraft (Extra 300)
<b>Pilot-1</b>	Physical action by pilot
<b>Pilot-2</b>	Physical action by copilot
<b>SS2 Cockpit</b>	Observed action/status on instrument panel/ in general cockpit area
<b>SCAT-21</b>	Callsign for SS2
<b>Galactic-01</b>	Callsign for WK2
<b>Galactic-03</b>	Callsign for CHASE
<b>EXTRA</b>	Alternate callsign for CHASE
<b>-1</b>	Voice identified as the pilot of SS2
<b>-2</b>	Voice identified as the copilot of SS2
<b>-3</b>	Voice identified as the pilot of WK2
<b>-4</b>	Voice identified as the copilot of WK2
<b>-5</b>	Voice identified as the flight test engineer of WK2
<b>-?</b>	Voice unidentified
<b>*</b>	Unintelligible word
<b>#</b>	Expletive
<b>@</b>	Non-pertinent word
<b>( )</b>	Questionable insertion
<b>(( ))</b>	Material Inserted from an alternate video/audio source
<b>[ ]</b>	Editorial insertion
<b><i>Italics</i></b>	Narrative of visible cockpit action or event

Note 1: Times are expressed in Universal Coordinated Time (UTC).

Note 2: Generally, only radio transmissions to and from the accident vehicle and carrier vehicle were transcribed.

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

Note 5: A acronym spoken phonetically is spelled phonetically and capitalized. An acronym spoken by individual letter is delineated by a hyphen between capitalized letters.

**SS2**

**WK2**

**RDO**

**HOT-1**

16:28:20.08 how's the P-S-C doing?

**Pilot-1**

16:28:20.40 *[Reaches for and touches Lower right outer knob of the center MFD, to select RKT master page. Uses inner knob to get to CTN sub page.]*

**SS2 Cockpit**

16:28:29.70 *[Center MFD fades to black.]*

**HOT-1**

16:28:29.92 [sigh] oohhhggg.

**HOT-2**

16:28:31.09 ughhh.

**HOT-2**

16:28:32.68 there ya go.

**SS2 Cockpit**

16:28:32.93 *[Center MFD begins rebooting at splash screen]*

**HOT-2**

16:28:34.25 base we just had a uh center M-F-D failure, with uhh @, moving the uhh, right lower small knob.

**BASE**

16:28:45.16 base copies and were, uh, seeing it rebooting on the, uh, big screen.

**HOT-1**

16:28:52.78 I think that's a first. at least in the airplane.

**HOT-2**

16:29:08.83 I'm gunna go ahead and pull it up on my side.

**SS2**

**WK2**

**RDO**

**Pilot-2**

16:29:10.90 *[Reaches toward own PFD and makes softkey input]*

**SS2 Cockpit**

16:29:17.50 *[Center MFD finishes rebooting]*

**Pilot-1**

16:29:19.93 *[Reaches toward and manipulates lower right center MFD knobs. Selects RKT master page.]*

**HOT-2**

16:29:25.93 alright, uhh, I'm selecting P-F-D on my side again...and I'm punching out the lights.

**Pilot-2**

16:29:29.20 *[Reaches toward softkey and selects PFD screen.]*

**Pilot-2**

16:29:35.37 *[Punches out (deselects) annunciator lights.]*

**Pilot-1**

16:29:44.20 *[Finishes manipulating Center MFD. Leaves screen at COM master page and COM subpage and puts hands in lap.]*

**HOT-2**

16:29:49.75 alright thirty thousand foot checks. ready for that?

**HOT-1**

16:29:51.90 ready.

**HOT-2**

16:29:53.03 alright, cabin altitude is fifty-three hundred.

**Pilot-1**

16:29:56.80 *[Removes oxygen mask from helmet.]*

**HOT-1**

16:29:56.90 [Sound similar to the ambient noise of free air flowing around the pilot's facemask mounted microphone.]

**HOT-2**

16:29:58.60 and delta P is seven point niner.

**Pilot-1**

16:30:00.03 *[Switches O2 regulator OFF.]*

**HOT-2**

16:30:04.22 oxygen mask(s) can come down.

**HOT-1**

16:30:05.63 off left and the regulator off left.

**Pilot-2**

16:30:05.77 *[Removes mask from right side of helmet.]*

**Pilot-2**

16:30:06.23 *[Reaches for unseen control on right side of instrument panel.]*

**Pilot-2**

16:30:14.03 *[Closes isolation valve on the center console.]*

**Pilot-2**

16:30:16.53 *[Touches soft key on right PFD, likely the timer.]*

**HOT-2**

16:30:18.41 alright, isolation valve is closed, starting the timer.

**Pilot-1**

16:30:21.00 *[Takes drink of water.]*

**HOT-2**

16:30:49.03 thirty seconds to go.

**SS2**

**WK2**

**RDO**

**HOT-1**

16:30:52.75 alright, thin layer here at uh thirty-two thousand looks like tops probably thirty-five or so, maybe thirty-eight.

**HOT-1**

16:31:10.44 call it just, uh, thin cirrus

**HOT-2**

16:31:16.87 alright there's, uhh, one minute, rates, uh, less than a hundred feet per minute.

**Pilot-2**

16:31:29.20 *[Opens isolation valve on the center console.]*

**Pilot-2**

16:31:31.70 *[Reaches toward right hand side of instrument panel and manipulates a control. [primary air on]]*

**HOT-2**

16:31:37.88 'kay, can put your, uh, mask and regulator back on.

**Pilot-2**

16:31:40.13 *[Starts putting O2 mask back on.]*

**Pilot-1**

16:31:41.10 *[Starts putting O2 mask back on.]*

**HOT-2**

16:31:44.95 and WhiteKnight, Spaceship's ready for the climb.

**Pilot-1**

16:31:51.23 *[Reaches toward oxygen regulator with left hand and manipulates a control(s).]*

**SS2**

**WK2**

**RDO**

**HOT-1**

16:32:00.35 alright oxygen to a hundred percent for pre-breathe. let's see if we can get some heat soak in here as well.

**HOT-2**

16:32:03.57 copy.

**Pilot-2**

16:32:07.23 *[Reaches and looks toward right side of instrument panel and manipulates control(s).]*

**HOT-1**

16:32:07.52 full hot on the...

**HOT-2**

16:32:09.10 gunna sweat me out, huh?

**HOT-1**

16:32:11.23 well if it gets too hot we can turn it down.

**HOT-1**

16:32:15.26 are you hot right now?

**HOT-2**

16:32:16.44 naw.

**HOT-2**

16:32:19.72 alright full hot is selected, uh, thirty thousand foot checks are complete.

**Pilot-2**

16:32:20.77 *[Removes hand from right portion of instrument panel.]*

**BASE**

16:32:30.62 galactic one, base is green for climb.

**RDO-4**

16:32:35.60 base, galactic one copies.

**SS2**

**WK2**

**RDO**

**Pilot-2**

16:32:46.60 *[Reaches behind pilot seat.]*

**Pilot-2**

16:33:10.60 *[Finishes reaching behind pilot seat.]*

**Pilot-1&2**

16:33:12.20 *[A movement of the co-pilot's head momentarily exposed the oxygen regulator panel to the camera's view. The Oxygen Regulator Panel Diluter Lever (white) on the co-pilot side appears in the up (100%) position. The position of the Emergency Lever (red) appears to be at "Normal" detent. The position of the Supply Lever (green) is indiscernible. The pilot's oxygen panel settings also appear nominal for this stage of flight.]*

**BASE**

16:33:28.24 scat two-one, base, we are ready for INTER O-V ((checks)) \* \*.

**HOT-2**

16:33:33.19 copy. alright rocket motor initialization checks.

**Pilot-2**

16:33:38.97 *[Selects RKT master page on center MFD. Then selects VALVE subpage.]*

**HOT-2**

16:33:45.65 alright. ready for INTER OV?

**HOT-1**

16:33:47.35 ready.



**SS2**

**WK2**

**RDO**

**Pilot-2**

16:33:48.03 *[Reaches toward INTER-OV switch.]*

**HOT-2**

16:33:49.52 three. two. one. mark.

**Pilot-2**

16:33:52.47 *[Manipulates INTER-OV switch.  
[Holds switch in EQUALIZE  
position].]*

**HOT-2**

16:33:59.92 (right) pressure is stable.

**Pilot-2**

16:34:01.83 *[reaches right hand toward soft key  
on the Left side of the PFD.]*

**BASE**

16:34:07.29 base has good ((Inter  
O-V)).

**HOT-2**

16:34:11.64 holding for twenty seconds, ten  
seconds to go.

**HOT-2**

16:34:25.10 complete.

**Pilot-2**

16:34:25.47 *[Removes left hand from INTER-OV  
switch.]*

**Pilot-2**

16:34:26.17 *[reaches left hand toward soft key on  
left side of PFD. Presses soft key  
twice. [stop and clear timer]]*

**Pilot-2**

16:34:28.40 *[Manipulates lower right knob(s) on  
center MFD to reach the CTN  
subpage of the RKT master page.]*

**SS2**

**WK2**

**RDO**

**HOT-1**

16:34:29.91 alright we're at the top of the, uhh,  
cirrus layer here at thirty-six  
thousand.

**HOT-2**

16:34:33.38 alright temperatures look good.

**Pilot-2**

16:34:39.77 *[Manipulates center MFD to display  
VALVE sub page.]*

**HOT-3**

16:34:46.92 @?

**HOT-4**

16:34:48.23 yes sir

**HOT-3**

16:34:50.68 just coming up to the turn  
towards DEATH [user  
defined fix].

**HOT-3**

16:34:55.58 you have control.

**HOT-4**

16:34:56.52 'kay, I have the controls,  
watching the speed and  
the mach.

**HOT-3**

16:34:59.08 I'll take the radio.

**HOT-4**

16:35:03.06 start(ing) the turn.

**HOT-2**

16:35:03.90 alright INTER OV pressures greater  
for... stable for greater than thirty  
seconds, L minus ten checks are  
next.

**SS2**

**WK2**

**RDO**

**BASE**

16:35:11.27 ((scat)) two-one, base  
((copies and if you've got  
time we'd like to do a  
couple more directional  
antenna checks.))

**HOT-1**

16:35:16.89 alright base you're starting to come in  
scratchy around that last call. it's  
probably a good place to do it.

**HOT-3**

16:35:25.60 have you got your I-C-S  
switch (flipped)?

**HOT-4**

16:35:32.22 what's that?

**HOT-3**

16:35:39.72 ((like you)) have NAV to  
(DEATH)?

**HOT-4**

16:35:41.70 okay, direct DEATH.

**HOT-4**

16:35:44.49 okay.

**HOT-2**

16:36:21.99 and base we've heard no further  
transmissions on comm since your  
last.

**BASE**

16:36:26.65 yeah copy that, we're  
switching antennas right  
now.

**HOT-2**

16:36:30.34 copy.

**SS2**

**WK2**

**RDO**

**HOT-3**

16:37:50.19 bottle pressure's good.

**HOT-1**

16:37:56.91 you have any, uh, geographic features...out that window?

**HOT-4**

16:38:02.83 nothing here.

**HOT-3**

16:38:03.34 no, not yet.

**HOT-2**

16:38:03.68 yeah I can, I can kinda make out some of the hills and stuff, saw the river a minute ago... but it's definitely difficult with the sun shining through it.

**BASE**

16:38:31.34 ((scat two-one, scaled base, how do you read?))

**HOT-2**

16:38:36.07 loud and clear.

**BASE**

16:38:38.69 \* \* \*.

**RDO-3**

16:38:47.15 galactic zero-three from zero-one, you're loud and clear.

**Pilot-2**

16:38:59.13 *[Manipulates center MFD to display COM master page, COM sub page.]*

**HOT-1**

16:39:01.15 I didn't hear Zer... I didn't hear him check in.

**SS2**

**WK2**

**RDO**

**HOT-3**

16:39:01.65 I thought I was on mission.

**HOT-2**

16:39:04.69 yeah he wasn't, he wasn't on mission.

**HOT-1**

16:39:06.05 oh, ok.

**HOT-2**

16:39:14.47 Uh, @, was the extra wasn't on mission frequency was he?

**HOT-3**

16:39:17.26 No I don't think he was, it was my mistake.

**HOT-2**

16:39:20.66 yeah we just wanted to check cause we didn't hear him.

**CHASE**

16:39:32.19 scaled base, extra is airborne.

**BASE**

16:39:35.53 copy all.

**RDO-3**

16:39:40.27 ((extra, from galactic zero-one, you are loud and clear))

**CHASE**

16:39:41.83 ((got you loud and clear galactic zero-one. scaled base, extra is airborne.))

**RDO-2**

16:39:47.26 extra from scat two-one, (loud and clear).

**SS2**

**WK2**

**RDO**

**CHASE**

16:39:50.73 loud and clear scat two-one.

**HOT-4**

16:39:53.04 alright, we have fuel cooler.

**HOT-3**

16:39:55.93 yup, so fuel coolers closed.

**HOT-3**

16:40:01.26 yes, so @ have you got fuel cooler indications on your kneepad?

**HOT-5**

16:40:05.23 I've only got one.

**HOT-3**

16:40:06.25 okay, okay, they're going to close.

**HOT-5**

16:40:12.69 yeah I show it movin'. oh, maybe they're all four there? never mind, I've got 'em all.

**HOT-3**

16:40:16.35 uh huh.

**HOT-5**

16:40:17.05 they're all movin'

**BASE**

16:40:25.09 ((galactic one,)) scaled base, ((we)) are good for the climb past forty.

**SS2**

**WK2**

**RDO**

**RDO-3**

16:40:29.46 ((scaled base, for  
galactic)) zero-one  
copied.

**HOT-5**

16:40:33.05 alright, all four are  
closed.

**HOT-3**

16:40:34.77 excellent, thank you.

**HOT-3**

16:40:50.68 the next is the L minus  
ten.

**HOT-5**

16:40:53.81 like we're gunna be good  
on pylon bottle temp.

**HOT-3**

16:40:58.61 good.

**HOT-5**

16:41:00.60 and press[ure]?

**HOT-3**

16:41:03.30 yup.

**HOT-2**

16:41:12.81 Uhh, @, we're just getting an  
intermittent caution on the T Pad for  
DAS battery current and it's just  
showing a negative, uh, point zero  
one.

**HOT-1**

16:41:26.09 I think uh until pylon power turns off  
it's not going through that. base is  
that correct?

**HOT-2**

16:41:42.57 that makes sense. it's a higher

**SS2**

potential so it just uses the pylon current.

**WK2**

**RDO**

**HOT-1**

16:42:26.81 I have visa, visibility's startin' to improve a little bit on the left side.

**HOT-2**

16:42:31.54 yup. same on the right.

**HOT-1**

16:42:39.66 (uh) I got pretty good S-A out the right, see the... hills now, to the north, it's, uh, ...not great.

**HOT-2**

16:42:52.25 [cough]

**Pilot-2**

16:43:00.40 *[Manipulates center MFD to scroll through pages to briefly reach the ECS master page PRESS sub page, then scans ECS master TEMPS subpage, returns to display COM master page, COM sub page.]*

**JOSHUA**

**APP**

16:41:58.39 galactic zero-three traffic west and two miles ((maneuvering D-C three, one zero thousand.))

**CHASE**

16:42:05.08 galactic zero-three's looking... ((galactic zero-three's visual.))

**JOSHUA**

**APP**

16:42:09.86 ((galactic zero-three)) roger.



**SS2**

**WK2**

**RDO**

**HOT-1**

16:43:44.87 amazing how much, uh, rate of climb  
you lose at the very end.

**HOT-4**

16:44:11.20 we need to work on, uh,  
card six point twelve.

**HOT-3**

16:44:14.97 yup.

**HOT-2**

16:44:20.39 showin', uh, three degrees beta on the  
FADS.

**HOT-3**

16:44:29.45 ((it says at a hundred and  
forty KEAS [Knots  
Equivalent Airspeed]))

**HOT-4**

16:44:32.88 ((oh... at...)) max beta is  
ten at one forty.

**HOT-3**

16:44:36.42 uh, yeah, okay.

**HOT-4**

16:44:38.85 @, what do you show for  
beta?

**HOT-5**

16:44:41.17 stand-by

**HOT-5**

16:44:43.67 uhh, one point five.

**HOT-3**

16:44:46.21 plus one point five, yeah,  
I think the ball is slightly  
out to the right, isn't it?

**HOT-4**

16:44:52.44 yeah, let me step on that.

**SS2**

**WK2**

**RDO**

**HOT-2**

16:45:02.66 we're showin', uh, two degrees.

**HOT-4**

16:44:56.80 alright, how's that?

**HOT-5**

16:44:58.07 one point three, one point five.

**HOT-5**

16:45:07.38 one. two.

**HOT-5**

16:45:12.26 point three.

**HOT-4**

16:45:17.72 all I did was start an oscillation.

**HOT-5**

16:45:19.57 yup.

**WK2-3**

16:45:20.01 [light chuckling]

**HOT-3**

16:45:33.91 goin' to smack in a little bit of trim there, @.

**HOT-4**

16:45:36.54 yea, just a little bit of right.

**HOT-4**

16:45:42.98 okay.

**HOT-3**

16:45:52.18 Spaceship, from, uh, T-TOP, how's your sideslip?

**HOT-2**

16:45:55.55 we're oscillating between two and two point five degrees.

**SS2**

**WK2**

**RDO**

**HOT-3**

16:45:58.92 (roger.)

**HOT-3**

16:46:00.80 I think that's, that's gonna req... require a bit more. @ are you happy with me just, uhh...

**HOT-4**

16:46:04.95 okay, go ahead and flip it.

**HOT-3**

16:46:06.20 good.

**HOT-3**

16:46:10.03 settle down at that for a bit and...

**HOT-4**

16:46:11.58 alright.

**HOT-4**

16:46:14.24 the ball moved.

**HOT-5**

16:46:15.55 yup, showin' about zero now.

**HOT-2**

16:46:20.19 and we're showin', uh, one point five.

**HOT-4**

16:46:22.98 \* \* \*

**HOT-3**

16:46:22.98 \* one point five.

**HOT-4**

16:46:24.75 puttin' in some left roll trim to counter that.

**HOT-3**

16:46:39.33 Spaceship, from T-TOP,

**SS2**

**WK2**

**RDO**

confirm you're still at one point five.

**HOT-2**

16:46:41.99 (right now) it's coming down now, it's, uhh, oscillating we're at one degree currently.

**HOT-5**

16:46:56.63 good visibility now.

**HOT-4**

16:46:58.70 oh yeah.

**HOT-3**

16:46:59.65 yeah, look at that.

**HOT-3**

16:47:02.70 \* \* Spaceship you were stepped on there, say again your sideslip.

**HOT-2**

16:47:05.82 point five.

**HOT-3**

16:47:07.84 uhh, you happy with that? do you want us to try and take that out as well?

**HOT-2**

16:47:11.29 I think probably one more blip, uh, of trim for you guys will put it in close for us.

**HOT-3**

16:47:16.15 'kay, here we go.

**SS2**

**WK2**

**RDO**

**Pilot-1**

16:47:33.23 *[Reaches toward the SS2 Pilot Camera on the left side of the instrument panel and ensures it is attached securely.]*

**HOT-2**

16:47:40.14 that's point, uh, (oh) point five it's oscillating a little bit @.

**HOT-2**

16:47:46.15 point five, plus or minus point three.

**HOT-4**

16:47:50.28 there's a little right pedal.

**HOT-2**

16:47:52.45 uh, now its negative, so we're oscillating around zero,

**HOT-4**

16:47:57.58 alright, starting the turn.

**HOT-3**

16:47:59.35 okay.

**HOT-1**

16:48:02.10 uhh, seems good.

**HOT-2**

16:48:04.00 looks good over here @.

**HOT-3**

16:48:05.68 great.

**HOT-1**

16:48:09.24 good vis to the east and south.

**HOT-3**

16:48:11.88 it's looking much better now. out the right hand side.

**SS2**

**WK2**

**RDO**

**HOT-3**

16:48:50.61 two one zero at niner.  
[Switched to AWOS.  
Unheard on recording.]

**BASE**

16:49:06.19 scat two-one, base.

**HOT-2**

16:49:09.34 go 'head base.

**BASE**

16:49:11.07 yeah, can you just verify  
that your waypoints ((are  
sequencing properly?))

**HOT-2**

16:49:15.22 A-firm

**HOT-2**

16:49:24.71 we'll have to get a little bit past that,  
right, before it'll sequence?

**Pilot-2**

16:49:25.67 *[Points toward waypoint on PFD  
screen.]*

**HOT-1**

16:49:27.62 yeah, we'll see.

**HOT-1**

16:49:31.03 I've lost track of when it wor-  
doesn't. when it works, when it  
doesn't.

**HOT-2**

16:49:40.07 I don't know that'll work on the next  
sequence though cause that's a  
discontinuity.

**HOT-2**

16:49:48.50 after, uh, ERANG [user defined  
waypoint].

**SS2**

**HOT-2**

16:49:53.69 good sequence.

**WK2**

**HOT-4**

16:50:04.27 forty-five I-N-S altitude.

**HOT-3**

16:50:11.27 yup, that's good. well  
done @.

**HOT-3**

16:50:32.63 yeah, they're not  
sequencing are they?

**HOT-4**

16:50:34.66 yeah, okay.

**HOT-2**

16:50:56.62 and base, can you just give us an  
update on, uhh, wind trends and  
nitrous temps?

**HOT-2**

16:51:13.50 copy all.

**HOT-1**

16:51:15.00 what was that? two nine zero?

**HOT-2**

16:51:18.23 no.

**RDO**

**BASE**

16:51:06.66 ((copy, uh, winds are  
holding right now)) one  
((nine)) zero at eight knots.  
tre... trends are \*. ((stand  
by for nitrous.))

**BASE**

16:51:19.57 (('kay and scat two-one,  
nitrous temps are))  
confirmed good all  
((around.))

**SS2**

**HOT-2**

16:51:22.38 copy. two one zero at eight.

**WK2**

**RDO**

**BASE**

16:51:25.87 ((negative.)) one ((niner))  
zero \*.

**HOT-1**

16:51:29.42 one nine.

**HOT-3**

16:51:39.57 @, do you mind if I just  
give ((you)) nav to  
DROP [user defined  
waypoint] here?

**HOT-4**

16:51:43.89 okay.

**HOT-4**

16:51:48.29 how come the line  
doesn't... come all the  
way?

**HOT-3**

16:51:53.73 I don't know actually.  
why've we got a gap?  
don't know.

**HOT-3**

16:52:08.29 (passing) sixteen minutes  
to DROP [user defined  
waypoint].

**HOT-?**

16:52:10.11 [light chuckling]

**HOT-5**

16:52:17.84 yeah, you never ask, uh,  
mission what the winds  
situation is.



**SS2**

**WK2**

**RDO**

**Pilot-1**

16:52:17.97 *[begins brushing/dusting pilot side  
Backup Panel glareshield with right  
finger.]*

**HOT-3**

16:52:21.48 [light chuckling]

**BASE**

16:52:30.14 scat two-one, did you  
((call?))

**Pilot-1**

16:52:30.70 *[Finishes brushin/dusting pilot side  
Backup Panel glareshield with right  
finger.]*

**HOT-2**

16:52:32.63 negative.

**HOT-1**

16:52:35.98 alright, visibility looks great...or  
acceptable.

**HOT-4**

16:52:43.42 mach point five.

**HOT-1**

16:52:59.14 so let's talk through a center M-F-D  
fail. you'll go P-F-D.

**HOT-2**

16:53:03.11 yup.

**HOT-1**

16:53:05.22 watch those CAS messages like a  
hawk, we won't have audio.

**HOT-2**

16:53:10.72 yeah, so we'll uh...

**HOT-3**

16:53:11.87 is your I-C-S switch  
centered @?

**SS2**

**WK2**

**RDO**

**HOT-4**

16:53:16.67 yeah it's centered.

**HOT-3**

16:53:17.45 okay, thanks.

**HOT-1**

16:53:19.71 sorry, ours is engaged here, we like listening to you guys.

**HOT-3**

16:53:22.99 we really like listening to you too.

**HOT-1**

16:53:23.06 [background chuckling]

**HOT-3**

16:53:38.64 we're doing well on performance.

**HOT-5**

16:53:40.62 yeah, we are.

**HOT-3**

16:53:47.11 so, correct me if I'm wrong here, I think (the), uh...now we've achieved the minimum we can trade a little bit of altitude if we want to for speed, up to point five five.

**SS2 Cockpit**

16:53:47.57 *[Center MFD upper display auto sequences to display rocket information.]*

**HOT-2**

16:53:49.27 good sequence.

**SS2**

**WK2**

**RDO**

**HOT-4**

16:53:58.71 right, but..

**HOT-3**

16:53:59.94 there's plenty of, there's.  
there's time to do that but  
uh...

**HOT-4**

16:54:03.15 (yeah) try and get it high  
then dive down.

**HOT-3**

16:54:05.37 yeah.

**HOT-4**

16:54:06.78 so fourteen minutes.

**HOT-3**

16:54:08.26 yeah, I think we're we're  
plenty of time to do that,  
but, uh, preference was to  
go a little bit faster rather  
than, uh, higher and  
slower.

**HOT-4**

16:54:17.24 alright, but yeah we  
should go as high as we  
can and then, uh...

**Pilot-2**

16:54:18.83 *[Briefly checks shoulder harness.]*

**HOT-3**

16:54:19.85 exactly, yeah, and then  
dive into it or something.

**HOT-4**

16:54:23.81 (oh).

**HOT-5**

16:54:24.83 we are, uh, conning

**SS2**

**WK2**

**RDO**

[creating contrails] for  
@'s S-A.

**HOT-3**

16:54:27.44 good.

**Pilot-2**

16:54:34.20 *[Briefly checks shoulder harness  
again.]*

**Pilot-1**

16:54:34.60 *[Brushes/dusts pilot side Backup  
Panel glareshield with hand briefly.]*

**Pilot-2**

16:54:36.33 *[Reaches toward the rear of helmet,  
touches rear of helmet, touches  
headrest, moves head briefly back  
onto headrest.]*

**RDO-3**

16:54:36.59 [exhales] (sorry base,  
galactic one, go ahead.)

**Pilot-2**

16:54:39.00 *[Raises visor and adjusts glasses,  
lowers visor.]*

**BASE**

16:54:41.06 ((yeah we concur)) with  
your discussion. climb ((at  
this speed and then you  
can)) trade and gain, uh,  
((some altitude for,)) uhh,  
((point five five mach.))

**Pilot-1**

16:54:46.67 *[Removes cover on visor and places  
in right thigh pocket of flight suit.]*

**Pilot-2**

16:55:10.70 *[Briefly touches oxygen mask and*

**SS2**

*quickly taps left side of helmet.]*

**WK2**

**RDO**

**HOT-5**

16:55:21.90 that the big, uhh, Vegas  
solar farm off to the left?

**HOT-3**

16:55:25.85 uhh yeah.

**HOT-3**

16:55:31.66 lot of those around now.

**HOT-4**

16:55:33.25 yeah.

**HOT-1**

16:55:45.39 and base, uh, the P-S-C intermittent,  
uh, display do we anticipate any  
consequence of the, that fault during  
boost, any display anomalies that we  
should expect?

**BASE**

16:56:02.80 ((scat two one, base.  
negative. uh,)) it has been  
solid ((since takeoff)) and  
((uh)) we don't anticipate,  
uh, even if it goes  
((intermittent display, we  
don't an-anticipate any  
issues.))

**HOT-1**

16:56:11.66 okay. copy. thanks.

**Pilot-1**

16:56:34.20 *[Places head firmly against headrest,  
begins adjusting position of head  
while placed firmly against  
headrest.]*

**SS2**

**WK2**

**RDO**

**RDO-3**

16:56:43.38 base from ((galactic zero-one, we're just coming up on eleven minutes thirty.))

**HOT-1**

16:56:43.85 this headrest, least the height I'm at, when I press up against it I kinda lose the bottom half of the screen.

**Pilot-1**

16:56:44.67 *[Briefly removes head from being placed firmly against headrest and turns head slightly toward copilot side of the crew cabin while again pressing head firmly against headrest.]*

**Pilot-2**

16:56:47.07 *[Presses head firmly against headrest.]*

**Pilot-1**

16:56:48.17 *[Looks forward and firmly places and adjusts head against headrest.]*

**Pilot-1**

16:56:48.83 *[Motions with right hand toward lower portion of PFD.]*

**HOT-2**

16:56:49.44 right.

**Pilot-2**

16:56:51.53 *[Reaches both hands behind helmet and briefly touches headrest.]*

**Pilot-1**

16:56:53.97 *[Adjusts head and reaches with both hands behind helmet to touch headrest.]*

**SS2**

**WK2**

**RDO**

**HOT-2**

16:56:54.83 I remember doing that on, on P-F oh one, I took my head, consciously took my head off the headrest.

**Pilot-2**

16:56:58.00 *[Motions head briefly back and forth between normal seating position and holding head firmly against headrest.]*

**Pilot-1**

16:57:01.50 *[Returns to a normal seated position.]*

**Pilot-2**

16:57:01.57 *[Returns to normal seated position.]*

**Pilot-2**

16:57:06.73 *[Presses head firmly against headrest.]*

**MHV TWR**

16:57:08.69 ((galactic zero-one, tower,))  
I ((had)) missed the last call. did you say ten minutes?

**Pilot-2**

16:57:10.17 *[Returns to normal seated position.]*

**RDO-3**

16:57:14.43 ((uh, negative, uh, we're just, uh,)) (eleven minutes now,) we're showing eleven minutes now.

**MHV TWR**

16:57:18.84 ((tower,)) eleven minutes.

**Pilot-2**

16:57:26.33 *[Reaches left hand around behind*

**SS2**

*helmet, makes a fist shape with his left hand and places between his helmet and headrest. Firmly puts force on hand and subsequently the headrest also. Removes hand from behind helmet.]*

**WK2**

**RDO**

**HOT-3**

16:57:31.22 @, shall I take it now and you get ready for the L minus ten?

**HOT-4**

16:57:34.14 okay, you have the controls.

**HOT-3**

16:57:34.93 thank you very much, I have.

**Pilot-2**

16:57:37.23 *[Raises visor and adjusts glasses.]*

**Pilot-2**

16:57:42.13 *[Lowers visor. touches mask. places hand back on paper checklist.]*

**Pilot-1**

16:57:59.37 *[Removes oxygen mask from right side of helmet.]*

**HOT-1**

16:57:59.84 *[Sound similar to the ambient noise of free air flowing around the pilot's facemask mounted microphone.]*

**Pilot-1**

16:58:04.57 *[Takes sip from water bottle.]*

**HOT-4**

16:58:11.52 and @, can you find,



**SS2**

**WK2**

**RDO**

uhh, on the kneeboard,  
W-K two pylon arm  
heat?

**Pilot-1**

16:58:15.93 *[Replaces oxygen mask strap to right  
side of helmet.]*

**HOT-5**

16:58:17.90 pylon arm heat, stand-by.

**HOT-2**

16:58:19.22 I show L minus ten.

**HOT-1**

16:58:22.77 yup.

**HOT-5**

16:58:23.24 yeah, I believe its six C.

**Pilot-1**

16:58:24.07 *[Finishes replacing and adjusting  
mask.]*

**Pilot-2**

16:58:25.07 *[Touches hand to oxygen mask  
briefly.]*

**HOT-4**

16:58:25.82 ok, it needs to be above  
minus five, so that's  
good.

**HOT-5**

16:58:28.43 yup and the pressure's up  
too.

**RDO-3**

16:58:30.82 [high frequency tone]  
((galactic zero-one is at))  
nine minutes thirty, nine  
minutes thirty.

**SS2**

**WK2**

**RDO**

**HOT-4**

16:58:37.33 alright.

**BASE**

16:58:37.82 scat two-one, base is ready  
for ((L minus ten checks.))

**HOT-2**

16:58:40.56 alright.

**HOT-1**

16:58:40.95 roger, Spaceship commencing L  
minus ten.

**HOT-2**

16:58:44.52 P-S-C enable. go to the page  
[unintelligible]

**Pilot-2**

16:58:46.17 *[Manipulates center MFD to display  
RKT main page, VENT sub page.]*

**HOT-4**

16:58:46.94 now we have nav to  
DROP.

**HOT-4**

16:58:51.30 DROP [user defined  
waypoint] system \*

**HOT-2**

16:58:52.49 alright, here we go.

**Pilot-2**

16:58:52.67 *[Reaches left hand toward PSC  
enable switch]*

**HOT-2**

16:58:54.15 mark.

**Pilot-2**

16:58:54.60 *[Removes left hand from area near  
PSC enable switch]*

**SS2**

**HOT-2**

16:58:56.07 P-S-C active.

**WK2**

**RDO**

**HOT-4**

16:58:56.18 all green. hooks are locked.

**Pilot-2**

16:58:56.83 *[Manipulates center MFD to display RKT main page, VALVE sub page]*

**HOT-1**

16:58:58.80 good pressurization.

**HOT-4**

16:58:59.70 bottle pressure's good.

**HOT-4**

16:59:00.82 arm valve temperature is good.

**HOT-2**

16:59:01.17 (b) (4) coming to auto.

**Pilot-2**

16:59:03.20 *[Reaches left hand to (b) (4) RUN switch from "OFF" to "AUTO". Removes hand.]*

**HOT-2**

16:59:04.18 mark. good indication.

**Pilot-2**

16:59:06.10 *[Points to top of MFD screen.]*

**HOT-2**

16:59:07.87 loose items?

**HOT-1**

16:59:08.66 alright, secured left.

**HOT-2**

16:59:10.23 and secured right.

**HOT-2**

16:59:11.695 seatbelts and shoulder harnesses?

**SS2**

**WK2**

**RDO**

**HOT-1**

16:59:13.87 I am snug in the left.

**SS2 Cockpit**

16:59:14.93 *[Makes motion towards respective harness, both crew slightly wiggle in seat.]*

**HOT-2**

16:59:15.05 snug on the right.

**HOT-2**

16:59:16.25 flight plan set up?

**HOT-1**

16:59:17.95 we've got, uh... DROP spaceship WIF-left, runway three zero. winds are still favoring three zero.

**Pilot-2**

16:59:18.50 *[Reached toward but did not manipulate PFD.]*

**Pilot-1**

16:59:20.37 *[Switches PFD to COM master page, COM sub page.]*

**Pilot-1**

16:59:26.53 *[Switches PFD back to NAV master page.]*

**HOT-2**

16:59:27.03 okay, and uh, C-D-I selected?

**HOT-1**

16:59:29.47 alright, I've got selected left.

**Pilot-1**

16:59:30.00 *[Briefly points to CDI select region on PFD screen.]*

**HOT-2**

16:59:31.36 yeah, mine's selected right. batteries are coming on.

**SS2**

**WK2**

**RDO**

**Pilot-2**

16:59:31.57 *[Places left hand near instrument panel and selects Left then Right battery switches to ON.]*

**HOT-2**

16:59:35.80 pylon power is coming off.

**Pilot-2**

16:59:37.23 *[Uses left hand to place PYLON POWER switch to OFF.]*

**HOT-2**

16:59:39.07 electrical system?

**Pilot-2**

16:59:39.67 *[Manipulates center MFD to display ELEC master page.]*

**Pilot-2**

16:59:45.53 *[Points to center MFD with Left hand and makes a checking motion.]*

**HOT-1**

16:59:46.73 all looks good.

**HOT-2**

16:59:47.89 okay. pneumatics?

**Pilot-2**

16:59:48.53 *[Manipulates center MFD to display PNEU page.]*

**HOT-1**

16:59:50.43 greater than twenty-three, good regulator pressures.

**HOT-2**

16:59:53.65 right, uh, feather locks. here comes the locks.

**Pilot-2**

16:59:55.77 *[Places left hand on Feather Lock Handles. Favors Left side of the LT*

**SS2****WK2****RDO**

*and RT Feather Lock Handles]*

**Pilot-2**

16:59:56.80 *[Moves Feather Lock Handles slightly right out of the detent and down to the UNLOCK position.]*

**SS2 Cockpit**

16:59:58.03 *[FEATHER NOT LOCKED Light illuminates on the backup panel.]*

**Pilot-2**

16:59:58.10 *[Reaches UNLOCK position with Feather Lock Handles.]*

**HOT-2**

17:00:02.08 pressures...good indications... and locking.

**Pilot-2**

17:00:04.20 *[Briefly removes hand from Feather Lock Handles and motions finger toward center MFD.]*

**Pilot-2**

17:00:04.90 *[Places hand back on Feather Lock Handle and begins transiting handles toward the LOCK position.]*

**Pilot-1**

17:00:06.70 *[Places hand to remove glare from Backup Panel, looks toward Backup Panel.]*

**SS2 Cockpit**

17:00:08.10 *[FEATHER OK TO LOCK Light extinguishes on Backup Panel]*

**SS2**

**WK2**

**RDO**

**Pilot-2**

17:00:09.07 *[Reaches handle LOCK position, moves handles slightly left into detent, ensures handles are seated in LOCK detent.]*

**Pilot-2**

17:00:10.03 *[Motions with left fingers toward top of MFD/Backup Panel in a checking motion.]*

**HOT-2**

17:00:10.07 and show locked.

**HOT-2**

17:00:11.56 back-up indications look good.

**HOT-2**

17:00:13.56 pri and alt air's coming off.

**Pilot-2**

17:00:14.80 *[Reaches right hand toward right side of instrument panel.]*

**HOT-2**

17:00:16.92 isolation valve...

**Pilot-2**

17:00:17.87 *[Uses left hand to move Isolation Valve to the closed position.]*

**HOT-2**

17:00:19.01 ...it's closed.

**HOT-2**

17:00:22.51 pri and emergency regulators are comin' to auto.

**Pilot-2**

17:00:23.73 *[Uses left hand to move PRIMARY and EMERGENCY Regulator switches to AUTO position.]*

**SS2**

**WK2**

**RDO**

**HOT-2**

17:00:26.86 radios?

**Pilot-2**

17:00:28.43 *[Manipulates center MFD to COM main page, COM sub page.]*

**HOT-1**

17:00:29.95 alright, we have mission set, one and two.

**HOT-2**

17:00:32.67 okay, pitch and roll trim.

**HOT-1**

17:00:36.38 alright goin' to pri and, uh, T Top we're, uhh, stirring the stick and we're gonna go off I-C-S.

**Pilot-1**

17:00:37.27 *[Places right hand on STAB TRIM switches, after a pause, moves switches to the PRI position.]*

**HOT-3**

17:00:43.06 roger.

**HOT-2**

17:00:49.22 alright. pitch and roll trim functionality?

**HOT-1**

17:00:51.50 alright, trimming up...down.

**HOT-1**

17:00:56.71 good pitch functionality, setting minus nine.

**HOT-1**

17:01:10.04 alright, minus nine set...roll functionality...



**SS2**

**WK2**

**RDO**

**HOT-1**

17:01:17.93 good roll and, uh, release trims are set.

**HOT-2**

17:01:20.54 okay, tweak the pitch just a bit there.

**HOT-1**

17:01:24.38 alright, tweaked.

**HOT-2**

17:01:25.65 alright...roll boost?

**HOT-1**

17:01:28.42 roll boost coming on.

**Pilot-1**

17:01:29.17 *[Uses right hand to press ROLL BOOST pushbutton.]*

**HOT-2**

17:01:30.08 and verify operation.

**Pilot-1**

17:01:31.47 *[Moves stick laterally with both hands.]*

**HOT-1**

17:01:34.73 good roll boost.

**HOT-2**

17:01:36.30 okay, primary flight controls, dampers on?

**HOT-1**

17:01:40.00 dampers coming on, good lights...rudders are locked...stick is free... dampers off... rudders free... stick free.

**Pilot-1**

17:01:40.90 *[Uses right hand to move DAMPERS switch to ON, four white lights illuminate near DAMPERS switch.]*

**SS2**

**WK2**

**RDO**

**Pilot-1**

17:01:43.53 *[Presses firmly with feet against rudder pedals.]*

**Pilot-1**

17:01:44.60 *[Grabs sticks with both hands and begins moving control stick in a circular motion.]*

**Pilot-1**

17:01:46.43 *[Completes moving stick in a circular motion, removes right hand and moves DAMPERS switch to OFF position. Four white lights near the DAMPERS switch extinguish.]*

**Pilot-1**

17:01:49.83 *[Presses firmly against rudder pedals.]*

**Pilot-1**

17:01:52.00 *[Uses both hands to move control stick in a circular motion.]*

**Pilot-1**

17:01:53.13 *[Completes motion and removes both hands.]*

**HOT-2**

17:01:53.94 'kay, cabin altitude's five thousand five hundred feet.

**Pilot-2**

17:01:54.47 *[Uses left hand to point toward center MFD screen.]*

**HOT-2**

17:02:00.09 (and) WhiteKnight, Spaceship's complete with L minus ten.

**HOT-4**

17:02:04.62 copy. complete. and, uh,

**SS2**

**WK2**

**RDO**

we're going payload  
electrical power and  
payload E-C-S to off.

**HOT-2**

17:02:14.65 alright, five minutes out. L minus  
four is next.

**CHASE**

17:03:00.19 extra's visual.

**RDO-3**

17:03:03.62 roger extra.

**HOT-1**

17:03:05.19 alright, comin' up on four minutes.

**HOT-1**

17:03:19.16 four minutes.

**RDO-4**

17:03:22.68 and flight ((L minus four  
minutes.))

**HOT-2**

17:03:26.41 alright. rocket burn timer?

**Pilot-1**

17:03:28.93 *[Uses right hand to point toward  
center console, then quickly points  
toward center MFD.]*

**HOT-1**

17:03:29.16 set and verified.

**HOT-2**

17:03:30.44 alright, here comes the inter OV.

**Pilot-2**

17:03:32.57 *[Places left hand near INTER-OV  
switch, makes an upward motion  
with hand near switch.]*

**HOT-2**

17:03:35.551 alright, it's equalized.

**HOT-1**

17:03:36.17 some light turbulence here.

**HOT-2**

17:03:38.22 here comes the B-O-V.

**Pilot-2**

17:03:38.67 *[Removes left hand from area near INTER-OV switch, places left hand near BOV switch. Removes left hand from area near BOV switch.]*

**HOT-1**

17:03:42.42 light chop is, uh, maybe a better...  
better description.

**Pilot-2**

17:03:45.70 *[RMC STATUS GO lights illuminate green]*

**HOT-2**

17:03:47.29 R-M-C status?

**HOT-1**

17:03:48.75 alright, we've got BOV open, two  
green lights.

**HOT-2**

17:03:51.61 dampers?

**Pilot-1**

17:03:53.67 *[Uses right hand to select CTRL master page on PFD.]*

**Pilot-1**

17:04:00.87 *[Uses right hand to move DAMPERS switch to ON, four white lights illuminate near DAMPERS switch.]*

**SS2**

**WK2**

**RDO**

**HOT-1**

17:04:01.38 dampers are symmetric, had to put in, uh, quite a bit of left force to get 'em there.

**HOT-2**

17:04:07.19 okay...roll boost?

**Pilot-1**

17:04:09.50 *[Uses right hand to select NAV master page, sub page indiscernible on PFD.]*

**HOT-1**

17:04:09.74 roll boost is on.

**HOT-2**

17:04:11.67 speed brake?

**HOT-1**

17:04:13.27 it's disabled.

**Pilot-1**

17:04:13.80 *[Uses right hand and points to area near SPEED BRAKE pushbutton.]*

**HOT-2**

17:04:14.93 window heat's coming off.

**Pilot-2**

17:04:16.17 *[Moves left hand to area near WINDOW HEAT switch, manipulates switch.]*

**HOT-2**

17:04:18.74 M-F-D, uhh, A-D-C source auto.

**HOT-1**

17:04:21.66 alright, source auto set left.

**HOT-2**

17:04:23.34 and center and right. M-F-D CAS messages?

**SS2**

**WK2**

**RDO**

**HOT-1**

17:04:25.96 they're all out.

**HOT-2**

17:04:27.13 caution and warning lights?

**HOT-1**

17:04:27.96 all... all out.

**HOT-2**

17:04:30.05 transponder?

**Pilot-2**

17:04:31.67 *[Manipulates center MFD to COM main page, XPDR sub page.]*

**Pilot-2**

17:04:36.13 *[Manipulates soft keys on Left side of center MFD.]*

**Pilot-2**

17:04:40.73 *[Manipulates center MFD to COM main page, COM sub page.]*

**HOT-2**

17:04:43.81 alright.

**RDO-2**

17:04:46.14 S-S Two is squawking.

**HOT-2**

17:04:51.45 alright, release clearance...

**Pilot-1**

17:04:53.83 *[Uses right hand to point toward right side of instrument panel.]*

**Pilot-2**

17:04:55.00 *[Briefly points to lower section of center MFD in a checking motion.]*

**RDO-2**

17:04:57.52 [high frequency tone] Mojave Tower, scat two-one request landing clearance runway three zero.

**SS2**

**WK2**

**RDO**

**MHV TWR**

17:05:10.34 ((scat two-one, this is))  
Mojave ((tower.)) wind  
((direction estimated two  
three)) zero ((at niner.  
approach end of)) runway  
three zero ((winds. runway  
three zero, cleared to land.))

**RDO-2**

17:05:19.80 cleared to land (three zero scat two-one.)

**RDO-4**

17:05:25.47 ((joshua, galactic zero-one is two minutes from)) release.

**HOT-2**

17:05:27.31 L minus four checks are complete,  
@.

**HOT-1**

17:05:29.51 alright.

**HOT-1**

17:05:38.69 alright, you're clear to arm, uh, at  
pylon release, I'll call for fire, and  
uh...call the pitch up, pitch down,  
trim, feather unlock one point four.

**HOT-2**

17:05:54.11 I'll uh, I'll try to keep a hack on that  
three-forty-five as well.

**HOT-1**

17:05:57.54 okay.

**HOT-1**

17:06:12.02 alright, then after, uh, shutdown, roll  
boost, uh, while we have some speed,  
roll boost will come off. primary (R-

**SS2**

**WK2**

**RDO**

C-S) is uh, comin' on. set the, uh, attitudes...feather uh, up, at uh, apogee...reset trims for minus ten...you're cleared to feather at, uh, apogee, if I haven't called for it, and, uh, remind me on the uh trims, if I haven't gotten to 'em.

**HOT-1**

17:06:43.84 alright, the visibility's goin' down a little bit here...I still have lakebed, and uh...

**HOT-2**

17:06:52.68 L minus thirty.

**HOT-2**

17:06:55.41 alright, stick?

**HOT-1**

17:06:57.27 stick is forward.

**Pilot-1**

17:06:57.37 *[Places both hands on control stick and moves it to a forward position.]*

**Pilot-2**

17:06:58.40 *[Quickly moves left hand toward lower center console, then quickly moves left hand up to the LAUNCH CONTROL ARM switch.]*

**RDO-2**

17:06:59.98 armed. yellow light.

**Pilot-2**

17:07:00.40 *[Removes left hand from LAUNCH CONTROL ARM switch, an amber*

**BASE**

17:06:54.438 ((scat two-one, glide trims good)) green for release.



**SS2**

**WK2**

**RDO**

*colored arm pushbutton light below switch is illuminated.]*

**SS2-**

**Cockpit**

17:07:01.23 *[Pilot places head firmly against headrest and slightly readjusts his seated position. Remains with head positioned on headrest until vehicle breakup. Co-pilot's head is slightly off headrest and moves toward instrument panel as he reaches for switches on panel. At no time during the boost portion does co-pilot's head touch the headrest. There is slight noticeable vibration to the pilot's helmet due to it being pushed against the structure of the seat and minimal vibration noticeable to the co-pilot's helmet during boost portion of flight.]*

**Pilot-2**

17:07:03.30 *[Moves his left hand onto ROCKET MOTOR ARM AND FIRE panel and makes an upward motion in vicinity of a switch.]*

**Pilot-2**

17:07:14.50 *[Moves left hand near ROCKET MOTOR ARM AND FIRE panel.]*

**RDO-4**

17:07:15.92 ((five. four. three.)) two.  
one. release. release.  
((release.))

**SS2****WK2****RDO****HOT-?**

17:07:19.01 clean release.

**SS2 Cockpit**

17:07:19.27 *[There is a visible jolt to cockpit and occupants.]*

**HOT-2**

17:07:19.27 [mechanical sound associated with the operation of the SS2/WK2 release mechanism.]

**HOT-1**

17:07:19.51 fire.

**SS2 Cockpit**

17:07:20.00 *[Shadow of WK2's wing can be seen quickly crossing inside of cabin of SS2]*

**Pilot-2**

17:07:20.13 *[moves left hand toward ROCKET MOTOR ARM switch.]*

**HOT-2**

17:07:20.69 arm.

**Pilot-2**

17:07:20.87 *[Makes quick motions with his left hand near ROCKET MOTOR ARM and FIRE switches.]*

**Pilot-1**

17:07:21.20 *[Relaxes forward pressure on stick.]*

**HOT-2**

17:07:21.29 fire.

**SS2 Cockpit**

17:07:22.73 *[Both PFDs auto sequence to BOOST phase and graphically change.]*

**HOT-1**

17:07:24.46 [strained voice] good light.

**Pilot-2**

17:07:25.30 *[Makes contact with left hand on left side of the control stick. Fingers and thumb of left hand appear to be around left horn of control stick.]*

**Pilot-1**

17:07:25.90 *[Uses both hands on stick to make minor lateral movements to make left and right roll corrections.]*

**HOT-1**

17:07:26.28 [strained voice] yeehaw.

**Pilot-2**

17:07:26.80 *[Begins moving left hand off of left horn of control stick. Begins left hand movement toward Feather Lock Handles.]*

**SS2 Cockpit**

17:07:26.83 *[PFD speed display on both PFD auto switches from ADC to INS by displaying the KEAS gauge from a black to a greyish white background.]*

**HOT-2**

17:07:26.91 [strained voice] point eight.

**Pilot-2**

17:07:27.37 *[Places left hand on Feather Lock Handles.]*

**Pilot-2**

17:07:27.47 *[Moves Feather Lock Handles slightly right out of lock detent.]*

**Pilot-2**

17:07:27.57 *[LT and RT Feather Lock Handles appear wider than previously seen. Handles appear to slightly diverge.]*

**Pilot-2**

17:07:27.90 *[Co-pilot appears to be leaning forward and into a downward unlocking motion with his left arm and shoulder.]*

**Pilot-1**

17:07:27.99 *[Pilot's left thumb rapidly moved from right to left and back again in the immediate vicinity of the trim hat switch on the flight controls. The movement appeared consistent with a possible quick left lateral trim input.]*

**Pilot-2**

17:07:28.10 *[Left hand is briefly removed from Feather Lock Handles and LT and RT portions appear to converge.]*

**Pilot-2**

17:07:28.27 *[Left hand has shifted grip to LT side of LT and RT Feather Lock Handles.]*

**HOT-2**

17:07:28.39 *[straining] unlocking.*

**Pilot-2**

17:07:28.40 *[A slight right motion to move LT and RT Feather Lock Handles out of LOCK detents.]*

**Pilot-2**

17:07:28.43 *[A downward motion of Feather Lock Handles begins, handles appear to be slightly twisted with LT Feather*

**SS2**

**WK2**

**RDO**

*Lock handle lower than RT Feather  
Lock handle.]*

**Pilot-2**

17:07:28.60 *[Feather Lock Handles are in mid  
transit.]*

**Pilot-2**

17:07:28.90 *[Feather Lock Handles appear to  
have reached UNLOCK position.]*

**Pilot-2**

17:07:29.00 *[Relaxes Left hand grip on Feather  
Lock Handles while still touching  
mechanism.]*

**SS2 Cockpit**

17:07:29.57 *[FEATHER NOT LOCKED Light  
illuminates on backup panel.]*

**Pilot-2**

17:07:30.07 *[Moves left hand off of Feather Lock  
Handles.]*

**SS2 Cockpit**

17:07:30.67 *[There is a slight but noticeable right  
roll indicated on ADI on both PFDs.]*

**SS2 Cockpit**

17:07:30.97 *[FEATHER OK TO LOCK Light  
extinguishes, FEATHER NOT  
LOCKED Light remains  
illuminated.]*

**SS2 Cockpit**

17:07:31.40 *[Both pilots' bodies appear to begin  
to be pushed downward into their  
seats.]*

**HOT-1**

17:07:31.42 *[strained voice] pitch up.*

**HOT-2**

17:07:31.76 [strained voice] pitch up.

**Pilot-1**

17:07:31.79 *[Pilot's left thumb rapidly moved to a position just above the trim hat switch on the flight controls and remains near the hat trim switch until the end of the recording. During this time, no forward, aft or lateral trim input movements were seen.]*

**SS2 Cockpit**

17:07:31.80 *[Backup FEATHER POSITION INDICATOR Light appears to have moved slightly upward on scale. ADI begins showing a pitch up trend on both PFDs.]*

**Pilot-2**

17:07:31.80 *[Co-pilot's head appears to move noticeably forward.]*

**SS2 Cockpit**

17:07:32.03 *[Right roll indication on ADI on both PFDs appears to become more level.]*

**HOT-1&2**

17:07:32.26 [Sound of grunting]

**Pilot-2**

17:07:32.33 *[Co-pilot's head continues to move forward toward his lap. There is some movement of left hand off of left knee.]*

**Pilot-1**

17:07:32.37 *[Pilot's head begins to move off headrest and slightly forward.]*

**SS2 Cockpit**

17:07:32.47 *[There is a noticeable vibration to the cockpit image.]*

**SS2 Cockpit**

17:07:32.80 *[Both pilots' torsos appear to be slumped forward with their harnesses restraining their bodies. pilots' heads have been pushed forward toward control panel and almost into their laps.]*

**SS2 Cockpit**

17:07:32.80 *[End of recording. End of Transcript]*